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SELECTION, USE, AND MAINTENANCE OF RESPIRATORY PROTECTIVE DEVICES

BY

H. H. SCHRENK AND S. J. PEARCE

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I.C. 7236,
April 1943.

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

SELECTION, USE, AND MAINTENANCE OF RESPIRATORY PROTECTIVE DEVICES[1]

By H. H. Schrenk[2] and S. J. Pearce[3]

INTRODUCTION

There are several well-recognized procedures for controlling exposure to hazardous atmospheres in industry. They include (a) substitution of less toxic material, (b) enclosure of processes, (c) wet methods, (d) local exhaust, (e) general ventilation, and (f) use of respiratory protective devices. In addition to their employment as a control measure in occupational exposures, respiratory protective devices also are essential in emergencies that may arise from failure or improper use of other control equipment.

Respiratory protective devices usually are employed to supplement other methods of control, as temporary expedients, or when other methods are not readily applicable or practicable. It seems reasonable to assume, however, that where respirators are used consideration has been given to the factors involved and that the devices can provide satisfactory protection if used properly. Their use should not be arrived at simply by a process of elimination of other methods that are more difficult to apply.

ATMOSPHERIC CONTAMINANTS

Atmospheric contaminants include gases, vapors, dusts, fumes, mists, and fogs. Respiratory protection against these contaminants may be required for concentrations that are immediately dangerous to health or life after comparatively short exposures, or that may produce injury only after prolonged or repeated exposures. Also, it may be necessary to use such devices against

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1/ The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7236."

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a single type of contaminant, against a combination of various types, or in atmospheres deficient in oxygen.

TYPES OF RESPIRATORY PROTECTIVE DEVICES

To meet the conditions mentioned, various types of respirators have been developed. Two basic principles have been utilized in their development - purification of the inhaled air by removal of the contaminant (air-purifying respirators) and supplying a respirable atmosphere to the wearer from an uncontaminated source (atmosphere- (air- or oxygen-) supplying respirators).

Air-Purifying Respirators

Air-purifying respirators include canister gas masks and chemical cartridge respirators for removing gaseous contaminants and mechanical-filter respirators for removing particulate matter or dispersoids. Canister gas masks and chemical cartridge respirators may be equipped with filters for removing dispersoids, thereby giving protection against both gaseous and particulate contaminants. As these devices provide protection only by removing contaminants, it is obvious that sufficient oxygen must be present in the atmosphere to support life.

Canister gas masks. - A canister gas mask usually consists of a full facepiece connected by a flexible breathing tube to a canister that may be carried in a harness on the chest, under the arm, or on the back. The canister contains the materials for removing the contaminants and purifying the air. These materials remove the contaminants either by chemical reaction or by physical adsorption, as on activated charcoal. As no single substance has been discovered that will remove all types of gaseous contaminants, the canister fill depends on the type of contaminant against which it is designed to protect. Fortunately, materials are available that will protect against groups of compounds; therefore, a multiplicity of materials is not required. For example, activated charcoal will absorb organic vapors, and alkaline materials such as soda lime and caustite will remove acid gases. Ammonia may be removed by silica gel or by various materials impregnated with such substances as copper or cobalt salts. Carbon monoxide is removed by catalytic oxidation to carbon dioxide by hopcalite, a special preparation of manganese and copper oxides. The protection that a canister affords depends on the material with which it is filled. For example, a canister may be filled with activated charcoal alone and give protection only against organic vapors or it may be filled with all types of the materials mentioned and give protection against all gaseous contaminants. For protection against a single contaminant the use of a single absorbent is desirable, as the life of the canister is longer, thus providing more economical protection.

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It is therefore extremely important to know the contaminants against which a canister will protect. To assist users in easy identification, a classification of gas-mask canisters has been developed in conjunction with a color code. This code, which is an American standard used by all manufacturers of gas masks in the United States, is as follows:

Canister type letter	Contaminants protected against-	Colors
A	Acid gases	White.1/
B	Organic vapors	Black.1/
C	Ammonia	Green.
D	Carbon monoxide	Blue.
Ae, etc.	Dusts, fumes, mists, fogs, and smokes in combination with any of the above gases or vapors	One-half inch contrasting black or white stripe around the canister near the top.
AB	Acid gases and organic vapors	Yellow.
ABC	Acid gases, organic vapors, and ammonia	Brown.
N	All of the above atmospheric contaminants	Red. Filters are included in this canister, but stripes to indicate them are unnecessary.

1/ Canisters for a single gas or vapor other than ammonia or carbon monoxide shall have a 1/2-inch colored stripe around the canister near the bottom. The color of the stripe will be assigned.

Canister gas masks have been developed primarily for protection against atmospheres immediately dangerous to life and are used mainly in emergencies. Therefore, first consideration has been given to complete respiratory protection to prevent even momentary failure that might result fatally. These masks, however, are not designed for protection against extremely high concentrations, and in Bureau of Mines Approval Schedule 14E4/ concentrations are limited to 2 percent by volume, with the exception of ammonia, for which the limit is 3 percent. The service life of the canister depends on the individual characteristics and the amount of absorptive material used. Although these masks are designed primarily for emergency use, they will, of course, give good protection for nonemergency situations, and filters may be incorporated to remove particulate matter.

4/ Bureau of Mines, Procedure for Testing Gas Masks for Permissibility: Sched. 14E, December 24, 1941, 19pp.

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Chemical cartridge respirators. - Chemical cartridge respirators usually consist of a small cartridge or canister attached directly to a half-mask facepiece. The materials for removing the contaminants are the same or similar to those used in canister gas masks, and filters may be incorporated to remove particulate matter. These devices may be considered small gas masks and are designed for protection in atmospheres that could be breathed by workmen without protection, but that might be irritating or disagreeable or produce injury to health after prolonged or repeated daily exposures; hence, primary consideration has been given to lightness, compactness, and comfort.

Mechanical-filter respirators. - Mechanical-filter respirators usually consist of a filter arrangement of some fibrous material, such as felt or paper, in a holder connected directly to a half-mask facepiece. The filter consists of fine fibers crisscrossed to form a maze or intricate network of tortuous passages. The dust, fume, mist, and fog are removed by physical trapping when the air is drawn through this material. The filtering efficiency increases as the dust load on the filter increases. The service life of the filter, therefore, does not depend on recognizable leakage, as does that of the gas masks, but on increase in resistance of the filter to a point where resistance to inhalation becomes excessive or uncomfortable. Although the filters will remove all types of particulate matter, the extent to which the material is removed depends on the characteristics of the particles, such as size and state. Also, the amount of permissible leakage[5/] depends on the toxicological significance of the material. Therefore, various types of filters are used; that is, a filter may be satisfactory for silica dust and not satisfactory for a toxic dust such as lead or cadmium, owing to the greater toxicity of the latter. A filter that is satisfactory for dust (mechanically generated, as by grinding) may not be satisfactory for fume produced by heating or burning, as in lead burning, owing to particle-size differences. On the other hand, a filter satisfactory for silica dust is considered satisfactory for all other fibrosis-producing dusts and nuisance dusts; and a filter considered satisfactory for lead dust is considered satisfactory for other toxic dusts, the toxicity of which does not exceed significantly that of lead.

Mechanical filter respirators have been designed for protection against atmospheres that are not immediately harmful; therefore primary consideration has been given to lightness, compactness, and comfort.

5/ Bureau of Mines, Procedure for Testing Filter-Type Dust, Fume, and Mist Respirators for Permissibility: Sched. 21, August 20, 1934, 14 pp.

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Atmosphere-Supplying Respirators

Respiratory protective equipment that supplies a respirable atmosphere from a source independent of the wearer's immediate atmospheric environment is of two basic types - a hose type, in which air from an uncontaminated source is conveyed to the wearer through a hose or tube, and a self-contained type, in which a supply of oxygen is carried by the wearer.

Air-Supplying Respirators

The air-supplying respirators commercially available may be divided into three types: Hose masks, air-line respirators, and abrasive blasting helmets, hoods, or masks.

Hose masks. - Hose masks consist of a tight-fitting, full facepiece, breathing tube or tubes, a harness, a comparatively large-diameter, noncollapsible hose line, and a hand-operated blower. The harness and hose are strong enough for retrieving the wearer in an emergency, and the hose must not collapse under heavy weight and must not kink. The maximum length of hose approved by the Bureau of Mines[6/] is 150 feet. The use of a hand-operated blower assures that a second person will be present in the even of difficulty. Also, the attachment of the hose to the blower and the large diameter of the hose permit breathing without undue resistance, even though the blower is not operated. The intake to the blower must be in uncontaminated air.

Hose masks are sturdily constructed, as they are designed to be worn in atmospheres immediately dangerous to life and to afford protection against all types of atmospheric contaminants and atmospheres deficient in oxygen.

Special-type hose masks without blower and generally used with about 25 feet of hose also are available. Although the hose, breathing tubes, and facepieces are essentially the same as those for hose masks with a blower, the harness is much lighter and the device is designed for lightness, compactness, economy, and simplicity of operation. Such masks are designed for nonemergency use or for use in atmospheres not immediately dangerous to life.

Air-line respirators. - Air-line respirators usually consist of a high-pressure air-supply system, a hose of relatively small internal diameter, a detachable coupling, and either a full- or half-mask facepiece, or even a helmet or a hood. As the air for this type of respirator usually is supplied

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6/ Bureau of Mines, Procedure for Testing Supplied-Air Respirators for Permissibility: Sched. 19A, August 9, 1937, 21 pp.

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from a high-pressure compressed-air system, it must be checked to see that it does not contain objectionable or harmful contaminants. Dust from rust, oil mists, odors, and even carbon monoxide may be present if the compressor becomes too hot; therefore, critical attention should be given to the air supplied to these devices.

Although this respirator will give respiratory protection against all types of contaminants, it is designed for routine protection against concentrations of contaminants that are not immediately dangerous to life or health. It is thus limited, owing to the possibility of leakage around the half-mask facepiece and also to the fact that no provision is made so that the wearer can breathe respirable air, should the air supply fail.

Abrasive blasting respirators. - Abrasive blasting respirators are essentially air-supplying respirators that have been modified by the addition of a suitable covering to protect the head and shoulders against impact and abrasion by rebounding material. They are designed primarily for use in abrasive blasting operations and not for use in atmospheres that are immediately dangerous to life.

Oxygen-Supplying Respiratory Equipment

The most common devices for supplying oxygen to the wearer are self-contained oxygen breathing apparatus. These apparatus consist of a cylinder of compressed oxygen, a reducing valve, an admission valve, a breathing bag, breathing tubes and mouthpiece with valves for direction of inspired and exhaled air, a regenerator for removing carbon dioxide, and a cooler. They operate on a closed-circuit principle, and the entire device is worn by the user. When the cylinder valve is opened the oxygen flows through the reducing valve, thence through the admission valve, into the breathing bag, until the bag is expanded to a point at which the admission valve automatically cuts off the supply of oxygen. Oxygen is breathed from the bag, and the exhaled air passes through the regenerator to permit removal of carbon dioxide, thence through a cooler, and back to the bag. As oxygen is consumed, the bag tends to collapse, and the admission valve automatically admits additional oxygen.

Self-contained oxygen breathing apparatus give respiratory protection against all types of atmospheric contaminants in any concentration that can be endured by the skin but require gas-tight goggles in atmospheres irritating to the eyes. They also protect against atmospheres deficient in oxygen and are designed for protection against atmospheres that are immediately dangerous to life.

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SELECTION OF RESPIRATORS

The use of respiratory protective devices as a control procedure requires as much consideration as any other control method. In the selection of a respirator, thorough consideration should be given to the various factors involved, such as (a) the chemical, physical, and toxicological properties of the substances against which protection is required; (b) the effect of the processes and conditions of use of the substances as they relate to the possible formation of significant secondary products; (c) the processes and conditions of their use as they relate to the dissemination of contaminants; (d) an evaluation of actual and potential hazards to determine whether conditions immediately dangerous to life or health might arise or whether injurious effects would be produced only after prolonged or repeated exposures; (e) the nature of the duties to be performed by the wearer of protective devices as they relate particularly to restriction of movements; (f) an understanding of the principles, design, scope of use, limitations, advantages, and disadvantages of the respiratory protective equipment available.

Virtually all applications of respiratory protective devices are specific and require individual attention. Examples of typical conditions with indication of choice of appropriate respiratory protection are given.

Atmospheres Deficient in Oxygen

Atmospheres deficient in oxygen may be extremely hazardous and immediately dangerous to life. Only oxygen breathing apparatus or a hose mask with blower should be chosen for protection under such conditions. Final choice between these two devices will depend on working conditions.

For example, for rescue work in mines, the men must proceed for considerable distances from a source of fresh air. Obviously, hose masks would not be satisfactory, as wearers are limited to a distance of 150 feet; therefore, oxygen breathing apparatus must be used. However, for use in entering confined spaces, such as tanks and manholes, hose masks are generally preferred because they are easier to maintain and relatively little training is required to use them. Air-purifying devices should never be worn in atmospheres deficient in oxygen.

Very High Concentrations of Toxic Gases and Vapors

By very high concentrations is meant those exceeding 2 or 3 percent. Either oxygen breathing apparatus or hose masks with blowers are the logical choice, and again final selection will depend on working conditions. Although gas masks might afford some protection, they would not be a good choice,

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because very high concentrations indicate a confined space with possibility of low oxygen; moreover, the absorbents would be used up rapidly. The marked discomfort produced by such irritating gases as ammonia and sulfur dioxide and the danger of poisoning through the skin by absorption of hydrogen cyanide limit the concentrations that can be entered.

Moderately High Concentrations of Toxic Gases and Vapors

Concentrations referred to here are those not exceeding approximately 2 percent but nevertheless immediately dangerous to life. Oxygen breathing apparatus would, of course, be applicable, as would hose masks with blowers and gas masks. Owing to their weight and maintenance and training requirements, oxygen breathing apparatus probably would not be used. The hose mask would be satisfactory and might be chosen if the encumbrance of the hose line were not too great. The most probable choice would be a gas mask, because of its light weight, ease of maintenance, and the small amount of training required by the wearer. The appropriate canister should, of course, be chosen.

Low Concentrations of Toxic Gases and Vapors

Low concentrations are atmospheres that can be breathed without protection but that will produce discomfort and possible chronic injury after repeated exposure to them. Hose masks and oxygen breathing apparatus would give satisfactory protection, but they would be given little consideration for such a situation for the reasons already outlined. Gas masks, chemical cartridge respirators, or air-line respirators would be satisfactory. Final choice would depend on actual conditions and freedom of movement required by the worker.

Pneumoconiosis-Producing and Nuisance Dust

Air-line respirators and pneumoconiosis-producing and nuisance-dust respirators or all-dust respirators could be chosen. If the dust concentration is exceedingly high, air-line respirators would be preferable. If the conditions of work are such as to interfere with the use of an air line, mechanical-filter respirators will serve satisfactorily, even though they are awkward to wear for many kinds of work.

Toxic Dust

Air-line respirators, toxic-dust respirators, or all-dust respirators would be a logical choice. The final decision will depend on local conditions

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of work and the materials being used. Knowledge of the concentrations likely to be encountered and of the safe or permissible concentration is necessary in evaluating the protection afforded.

Fume

Fume is particulate matter formed by volatilization and condensation, as in lead burning. Fume is defined because it is a term used loosely to refer to gases, vapors, and particulate matter. Such usage is confusing and may lead to serious injury if a mechanical-filter fume respirator is used for protection against some toxic gas or vapor against which it affords no protection. For fume as defined above, air-line respirators or mechanical-filter fume respirators would be the logical choice, and final decision would depend on local working conditions.

Gases and Particulate Matter

Frequently protection must be afforded against a combination of gases and particulate matter (dust, fume, mist, and fog). If the atmosphere is not immediately dangerous to life, air-line respirators are generally recommended. However, gas masks equipped with a suitable filter or cartridge-type respirators equipped with a suitable filter may be used. Final decision not only would depend on the local conditions of work as they relate to freedom of movement but also on thorough consideration to ascertain whether gas masks or cartridge respirators would give the desired protection.

USE OF RESPIRATORS

Although choice of a suitable respirator is important, other considerations are equally so. Obviously, if a respirator is to do the job for which it is chosen, it must be worn properly and be kept in good condition. Frequently persons do not know how to wear a respirator, and if it is not clean it is unpleasant to wear. Better protection and fuller cooperation doubtless would be obtained if the respiratory protective devices were kept under the supervision of a responsible person who would see to it that the wearer is properly instructed in their use, that the devices are cleaned and disinfected regularly, and that they are maintained in first-class condition.

Instruction in Use of Respirators

No instructions are necessary when hard hats or hard-toed shoes are given to workmen, as they are used to wearing such articles. Too frequently respirators are handed out in a similar manner. Even the simplest respirator is comparatively much more complicated than protective hats or shoes

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and is a device that most workers are not accustomed to wearing. The principles on which each device is based, its field of use, and its limitations, as well as the essential parts, should be explained to the wearer in terms he can understand. Detailed instructions with practice should be given to all persons who are expected to wear such devices. Further, an explanation of the importance of wearing a respirator should be helpful in obtaining more complete cooperation.

For example, in the use of mechanical-filter respirators attention should be called to the importance of a good facepiece fit[7/] and proper but comfortable adjustment of the headband, and also to the fact that increased resistance to inhalation indicates that the filter should be cleaned or renewed.

In the use of gas masks good facepiece fit is also necessary, and the proper canister must be chosen. As the wearer depends on odor or irritation to warn when the canister is exhausted, he must be acquainted with the warning properties of contaminants for which protection is worn so that leakage will be detected readily. Persons using gas masks in toxic atmospheres should have had preliminary training in the use and limitations of the equipment.

All respirators approved[8/] by the Bureau of Mines are furnished with an approval label that give concise information on use and limitations. Also, more detailed instructions that have been reviewed by the Bureau accompany all approved devices. Both approval label and instructions should be consulted by the user.

Cleaning and Disinfecting Respirators

Respirators, particularly the facepieces, should be scrubbed daily after use with lukewarm water and soap. This not only is good hygienic paractice but also prolongs the life of the rubber, as otherwise the dirt, oil, and perspiration from the face may cause rapid deterioration. Respirators should also be disinfected at regular intervals. If a respirator is worn by the same person, disinfection once a week probably should be satisfactory in most instances, depending on conditions of use and thoroughness of cleansing with soap and water. A respirator that has been worn once should be disinfected before it is given to another person to wear.

7/ H. H. Schrenk, Testing and Design of Respiratory Protective Devices: Bureau of Mines Inf. Circ. 7086, 1939, 11 pp.

8/ Schrenk, H. H., List of Respiratory Protective Devices Approved by the Bureau of Mines: Bureau of Mines Inf. Circ. 7030R, 1941, 11 pp.

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There are several procedures for disinfecting respirators; however, as certain respirator parts may be damaged by the disinfecting agent, the manufacturer should be consulted as to the best procedure for his device. This warning is particularly pertinent at present, when the use of substitute materials is so common.

Common disinfecting procedures include scrubbing or immersing the respirator for 10 minutes in 70 percent alchohol, 2 percent cresol, or a solution of formalin made by mixing 1 part of 40 percent formaldehyde in 9 parts of water. When such agents as cresols are employed as disinfectants, the parts that come in contact with the skin should be rinsed thoroughly with water, as some persons are highly sensitive to such materials.

Cleaning and disinfecting afford an opportunity for cleaning or replacing filters, inspecting valves, headbands, facepieces, and metal parts that might be distorted.

Maintenance and Storage

A most important phase of any control procedure is maintenance. Choice of proper equipment and adequate instruction are completed projects, but maintenance is a continuous problem requiring constant attention. As such it should be supervised by someone thoroughly familiar with the apparatus being used.

Washing and disinfecting the device afford an opportunity to inspect it for minor repairs. In addition, it should be inspected thoroughly at monthly or longer intervals, depending on the apparatus, conditions of use, and storage. Devices for emergency purposes should be inspected after each use to assure that they will be in good condition and immediately available if an emergency arises. After the equipment has been cleaned and inspected and any necessary repairs are made, it should be stored properly. A good procedure is to have a central place of storage, possibly with substations at strategic points if the plant is large. Storage should be in essentially dust-proof containers away from sunlight and in a cool place (not near radiators or steam pipes). Small devices, such as dust or chemical cartridge respirators, can be kept in paper or cellophane bags. These devices may be numbered and assigned to some one person, who returns them at the end of the shift to the central station for cleaning and replacement of filter elements and for repairs if necessary. Thus, wearers are assured clean devices in good working order for each day's use. This program may be facilitated by assigning two respirators to each person, one being used while the other is being serviced.

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Larger devices, such as gas masks and hose masks, usually come equipped with a sturdy case or trunk that can serve as a storage place. If they are stored at strategic points for emergency use, they might be placed in a case with a glass window that requires breaking of a seal to assure that they have not been used or tampered with. The seal should bear the date of the last inspection.

SUMMARY

The selection of respiratory protective devices requires careful consideration of the hazards involved and knowledge of the limitations, advantages, and disadvantages of the various devices available. To obtain adequate protection, the wearer must be properly instructed, and the devices must be cleaned and disinfected regularly and maintained in first class condition.

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